RF power handling and more

Typical Pulses for Triple Resonance Inverse 5 mm H-C/N-D CryoProbes™ at 850 MHz

4.2 Pulse and power recommendations

Note: all values require a minimum relaxation delay *d1* of 1 s unless differently specified in footnotes [2].
Important: observe the separate notes on the following pages!

	5 mm 850 MHz TCI H-C/N-D CryoProbe™
^{1}H	
hard pulse [3] (max. length 1ms)	8.0 µs
hard pulse for lossy samples	Power level corresponding to 8.0 µs pulse for non-lossy sample
trim pulse p28 [4]	1 ms @ 8 µs 2 ms @ 11 µs
TOCSY spin lock [5]	120 ms @ 20 µs 400 ms @ 35 µs
ROESY spin lock	Up to CW for power level corresponding to a 80 µs pulse
WALTZ65 decoupling during ^{13}C-detection	Up to CW for power level corresponding to a 80 µs pulse
DIPSI2-decoupling in triple resonance	400 ms @ 35 µs
^{13}C	
hard pulse [6] (max. length 1000°)	12.0 µs
trim pulse [5]	2 ms @ 22 µs
CC spin lock [5]	40 ms @ 22 µs
CPMG REX	150 ms @ 12 µs up to 2 kHz
GARP4 decoupling [7]	250 ms @ 45 µs (> 142 ppm bandwidth)
Adiabatic decoupling	500 ms @ 55 µs Crp48,1.5,20.2 (> 170 ppm bandwidth)
selective pulses [8]	*G4*: 290 µs / *Q5*: 226 µs *Q3*: 180 µs *CHIRP*: 2 ms @ 22 µs
^{15}N	
hard pulse [6] (max. length 1000°)	32.0 µs
GARP4 decoupling [7]	125 ms @ 120 µs (> 134 ppm bandwidth) 250 ms @ 170 µs (> 95 ppm bandwidth) 1000 ms @ 350 µs (> 45 ppm bandwidth; sofast-HMQC)
CPMG T2 [9]	250 ms @ 40 µs (see warning [9]) 400 ms @ 50 µs
CPMG REX [10]	50 ms @ 40 µs up to 2 kHz 100 ms @ 40 µs up to 1 kHz
T1 rho [11]	100 ms @ 3 kHz 200 ms @ 1.5 kHz
^{2}H	
hard pulse (max. length 1000°)	100 µs
WALTZ64 decoupling	100 ms @ 250 µs
Z-Gradient	
Absolute max. current I_{max}	10 A
Max. overall length T_{max} [12]	10 ms @ 10 A

Table 1

RF power handling

What does “power handling” mean?

1. rf pulse deposit energy (heat) in the rf circuit and rf coils
2. Long pulses trains deposit more heat
3. Examples for long pulse trains:
   - CPD decoupling
   - Long CW irradiation: $T_1\rho$ experiments
   - Long CPMG sequence: T_2, REX

What might happen?

1. If deposited energy exceed specifications:
   - Excessive sample heating
   - Detuning of the rf circuit
   - Pulse width change: longer pulses which are difficult to control
   - Poor quality spectra

RF power handling

Will the CryoProbe be destroyed?

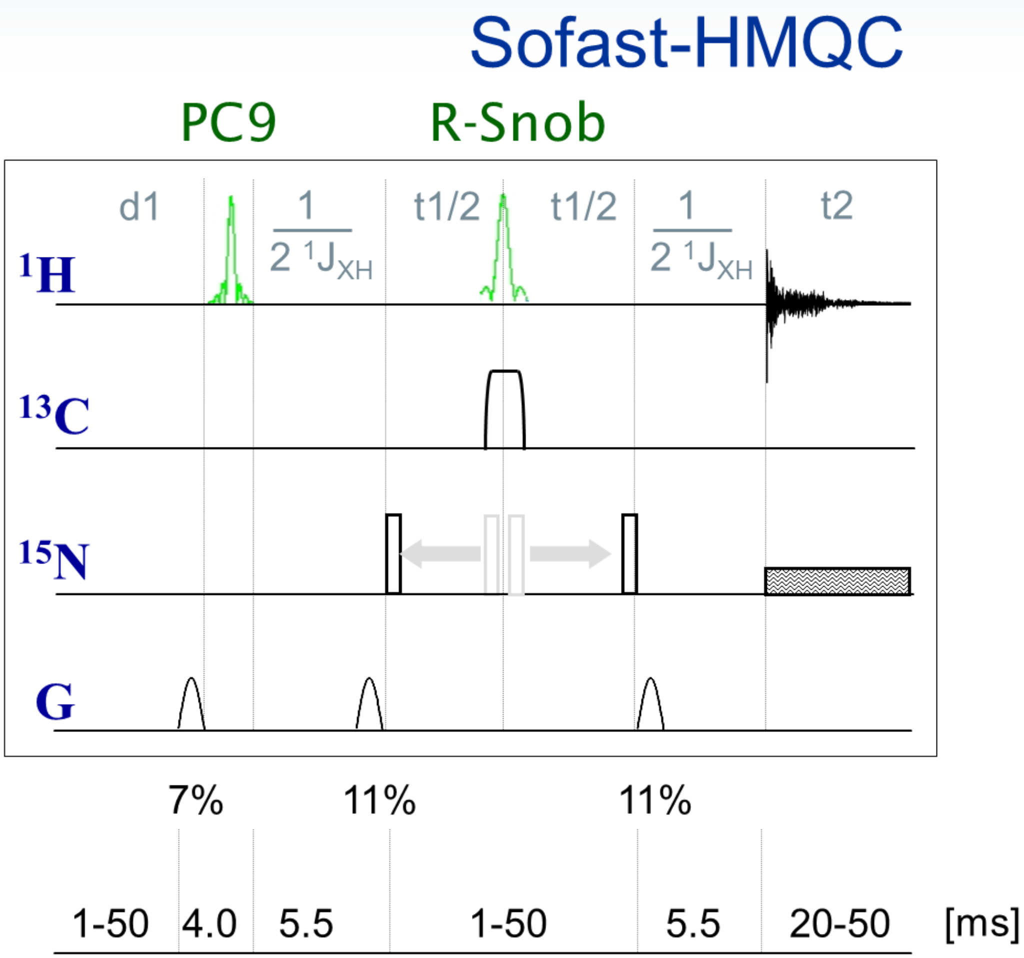
1. Power check of Topspin: ensures that the pulse voltage is not exceeded
   - Too high voltage ***WILL*** destroy the probe
   - Applying long pulses just close below the voltage limit are critical

RF power handling

Are there also be specifications for the allowed gradient power?

1. Yes
2. Why?
   - DC current is applied to a coil
   - The gradient coil behaves like a heating coil
   - DC current applied to long = long intense gradient pulses will overheat the wired
   - Wires will burn

RF power handling

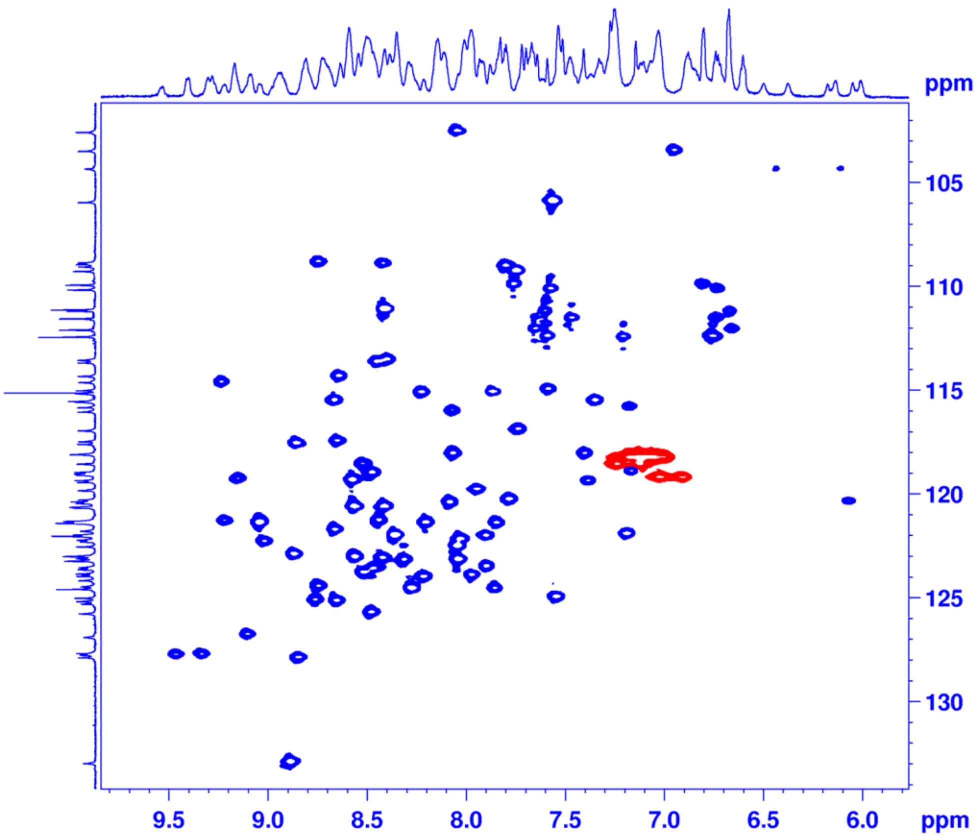


RF power handling

Sofast-HMQC

1mM Ubiquitin ($^{13}C/^{15}N$) in 90% H2O / 10% D2O

50 seconds acquisition time !



Acquisition Parameter:

AQ: 42 ms

D1: 8 ms

^{15}N decoupling: γB_1 of 892 Hz

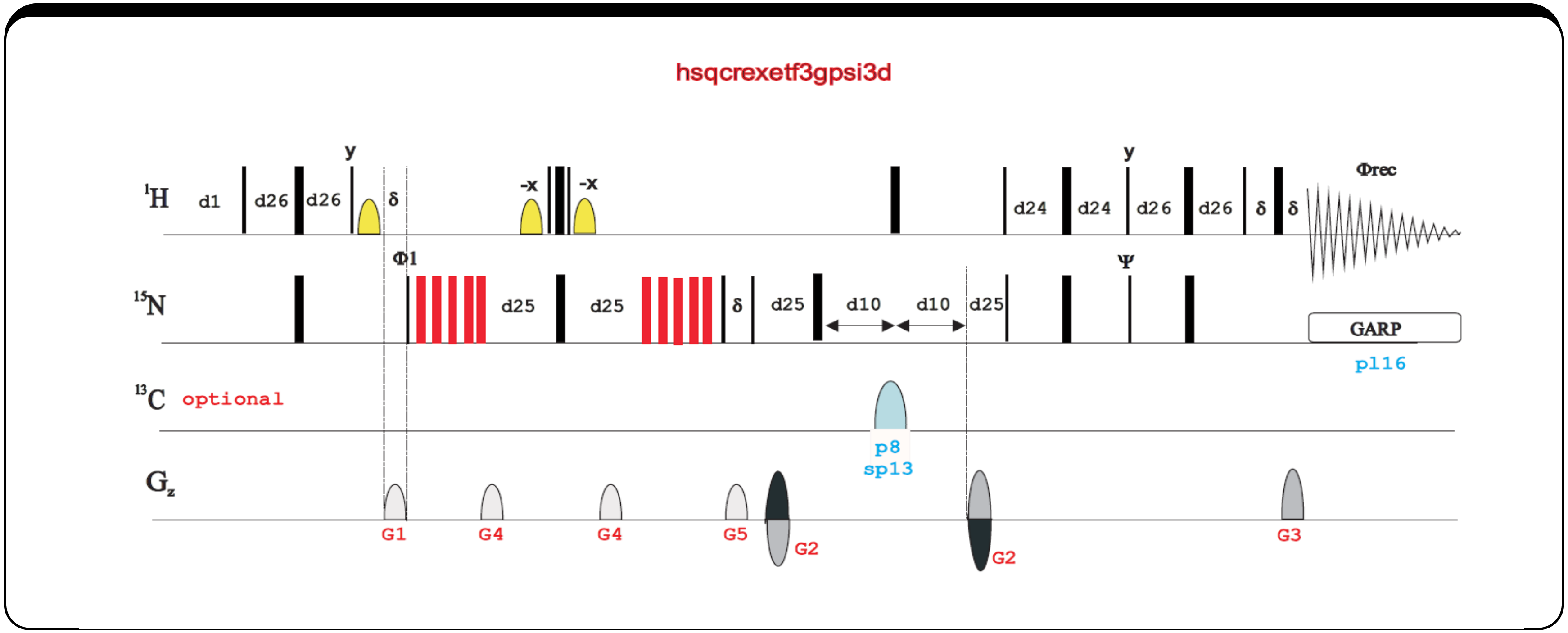
RF power handling

^{15}N-CPMG for relaxation dispersion experiment:

1. Duration (mixing time) is constant
2. Number of ^{15}N pulses is varied in order to change the effective γB_1 field

Challenge:

1. Short ^{15}N pulses to avoid off-resonance effects
2. High γB_1 field to allow experiment on small proteins/peptides



RF power handling

	5 mm 850 MHz TCI H-C/N-D CryoProbe™
^{1}H	
hard pulse [3)] (max. length 1ms)	8.0 µs
hard pulse for lossy samples	Power level corresponding to 8.0 µs pulse for non-lossy sample
trim pulse p28 [4)]	1 ms @ 8 µs 2 ms @ 11 µs
TOCSY spin lock [5)]	120 ms @ 20 µs 400 ms @ 35 µs
ROESY spin lock	Up to CW for power level corresponding to a 80 µs pulse
WALTZ65 decoupling during ^{13}C-detection	Up to CW for power level corresponding to a 80 µs pulse
DIPSI2-decoupling in triple resonance	400 ms @ 35 µs

RF power handling

	5 mm 850 MHz TCI H-C/N-D CryoProbe™
^{1}H	
^{13}C	
hard pulse [6)] (max. length 1000°)	12.0 µs
trim pulse [5)]	2 ms @ 22 µs
CC spin lock [5)]	40 ms @ 22 µs
CPMG REX	150 ms @ 12 µs up to 2 kHz
GARP4 decoupling [7)]	250 ms @ 45 µs (> 142 ppm bandwidth)
Adiabatic decoupling	500 ms @ 55 µs Crp48,1.5,20.2 (> 170 ppm bandwidth)
selective pulses [8)]	*G4:* 290 µs / *Q5*: 226 µs *Q3*: 180 µs *CHIRP*: 2 ms @ 22 µs

RF power handling

	5 mm 850 MHz TCI H-C/N-D CryoProbe™
^{1}H	
^{13}C	
^{15}N	
hard pulse [6] (max. length 1000°)	32.0 µs
GARP4 decoupling [7]	125 ms @ 120 µs (> 134 ppm bandwidth) 250 ms @ 170 µs (> 95 ppm bandwidth) 1000 ms @ 350 µs (> 45 ppm bandwidth; sofast-HMQC)
CPMG T2 [9]	250 ms @ 40 µs (see warning [9]) 400 ms @ 50 µs
CPMG REX [10]	50 ms @ 40 µs up to 2 kHz 100 ms @ 40 µs up to 1 kHz
T1 rho [11]	100 ms @ 3 kHz 200 ms @ 1.5 kHz

Gradient pulses

Z-Gradient		
Absolute max. current [10)]	10 A	10 A
Max.overall length [11)]	10 ms @ 10 A	10 ms @ 10 A

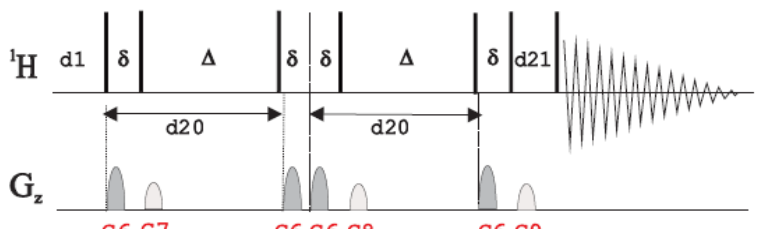
Note: some pulse sequences might have more gradients than you expect!

- Experiment with bipolar gradients used for diffusion/DOSY experiments

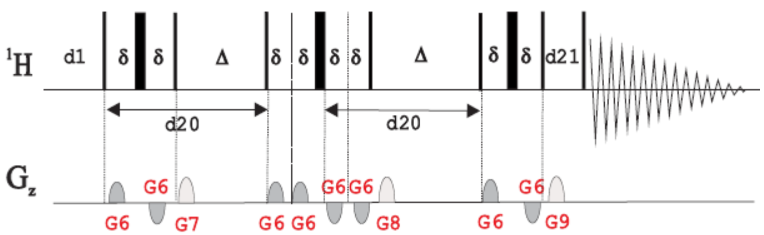
Gradient pulses DOSY

Double STimulated Echo (DSTE) for convection compensation

dstegp3s
dstegp3s1d



dstebpgp3s
dstebpgp3s1d



- LED also
- 3 spoil gradients
- 4 diffusion gradients

- same, but with bipolar gradients:
- LED and 3 spoil gradients (G7, G8, G9)
-
- bipolar gradients for diffusion (G6), makes 8 diffusion gradients!!!

NOTE: gradient limitation for CryoProbes: maximum 10ms@10A

example 1. SMSQ10.100 gradients with 2ms length, 100%: 5 x 2ms =10ms

example 2. SINE.100 gradients with 2ms length, 100%: 8 x 2ms x 0.67 = 10.72ms

because the area of a sine curve is 67% of the area of a square